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(72) Inventor: **Frediani, Lido**  
**10093 Collegno (Torino) (IT)**

(74) Representative: **Banfi, Paolo**  
**Blanchetti Bracco Minoja S.r.l.**  
**Via Rossini, 8**  
**20122 Milano (IT)**

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(71) Applicant: **Frediani, Lido**  
**10093 Collegno (Torino) (IT)**

(54) **Two-layer chrome-plating process**

(57) Disclosed is a galvanic chrome-plating process with a multiple layer of chrome, conducted in an electrolyte bath to which additives able to prevent microcracking of the first layer of chrome are added.

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## Description

## DESCRIPTION OF INVENTION

## FIELD OF THE INVENTION

[0001] This invention relates to the use of additives for chrome-plating baths and a process of chrome electro-deposition with the said additives.

## STATE OF THE ART

[0002] Chrome-plating, as normally performed, presents numerous drawbacks, the main ones being macrocracks or crazing in the case of deposits thicker than approx. 0.001 mm, which considerably reduce corrosion-resistance; low cathode efficiency; weak penetrating power (in terms of the percentage deviation of the objective distribution ratio of the metal by reference to the theoretical current distribution ratio, as defined by E. Haring and W. Blum); and weak covering power (defined as the minimum current density at which the chrome deposit begins to form); in addition, the internal tensions in the layer deposited reduce the fatigue resistance of the chrome-plated article.

[0003] The various proposed methods of eliminating macrocracks or crazing include high bath temperatures: macrocracks are considerably reduced at the temperature of approx. 70-80°C. However, the use of these high temperatures involves considerable practical difficulties and reduces the hardness of the chrome deposited. The residual tension must be eliminated by heat treatment of the chrome-plated articles at high temperature.

[0004] This invention relates in particular to hard chrome-plating, also known as industrial chrome-plating, which is designed to form chrome deposits that give the underlying metal high corrosion resistance and improved physical and mechanical properties. Its appearance can vary (bright, semi-bright, dull, etc.), as can its hardness, depending on the electrochemical process used. Microcracks may be deliberately introduced for various purposes (e.g. the hydraulic industry, chrome-plating of engine cylinders, etc.) which require lubricant to adhere well to the chrome-plated surface.

[0005] However, sufficient corrosion resistance is still required for these types of chrome deposit.

[0006] Chrome-plating, as normally performed in accordance with known processes, presents two main drawbacks:

- a) deposits thicker than approximately 0.001-0.002 mm are generally subject to cracking or crazing, which considerably reduces their corrosion resistance
- b) the internal tensions in the layer deposited reduce the fatigue resistance of the chrome-plated article.

[0007] Herein provided is a process for chrome electro-deposition in two layers, wherein the first layer of chrome has a hexagonal crystalline structure, with the result that the deposit is dull, with no cracks, and the second layer is a body-centred cubic lattice and is therefore bright, with microcracks.

[0008] Chrome-plating is widely used to protect metal, especially ferrous articles, against corrosion; there is consequently continual demand for industrial chrome-plating with electrolytic deposits of chrome which offer improved corrosion resistance.

[0009] This invention relates to electro chrome plating processes substantially based on improved chrome-plating baths, with which two or more layers of chrome with different crystalline structures are applied to the article to be chrome-plated using a single galvanic bath.

[0010] As known, a chrome bath obtained with pulsating waves is not cracked, and therefore offers high corrosion resistance. Conversely, its hardness and elasticity (resistance to thermal and mechanical shocks) is lower than that obtained by the conventional method, which means that the use of pulsating waves is not effective for industrial chrome-plating with the mechanical characteristics normally required.

[0011] To eliminate these drawbacks, as the market demands microcracked chrome, this invention uses the two (or more) chrome layer system. A first, non-cracked layer, obtained with the use of an electrolyte solution containing sulphobetaines of heterocyclic bases as additives to inhibit microcracking, is deposited, followed by a second, microcracked layer of chrome with the properties of hardness, elasticity and high protection normally required, because the first, uncracked layer prevents the cracks from reaching the metal base.

[0012] High corrosion resistance results from the choice of the correct thickness of the two layers.

[0013] The process in accordance with the invention is essentially based on the use of specific additives for the galvanic chrome-plating bath. In addition to the sulphobetaines mentioned above, represented by the general formula:

a)  $X^+(CH_2)_nSO_3^-$  wherein  $n = 1-3$  and X represents a nitrogen containing heterocyclic base selected from pyridine, pyridazine, pyrimidine, pyrazine, piperazine, methyl pyridine, imidazole, nicotinic acid and quinoline,

one or more of the following compounds may be used as additives:

b) heterocyclic bases quaternised with alkane mono- and disulphonic acids of general formula:

b')  $CH_3(CH_2)_nSO_3X$ , wherein  $n = 0-2$  and X is a protonated nitrogen-containing heterocyclic base of the type indicated in paragraph a) above, and

b")  $\text{XSO}_3(\text{CH}_2)_n\text{SO}_3\text{X}'$ , wherein  $n = 1-3$ , X and X' are protonated nitrogen-containing heterocyclic bases of the type indicated in paragraph a) above, or hydrogen, provided that at least one of X and X' is a nitrogen-containing heterocyclic base

c) sulphonamides of general formula:

c')  $\text{CH}_3(\text{CH}_2)_n\text{SO}_2\text{NH}_2$ , wherein  $n =$  integer from 0 to 4, and

c'')  $(\text{CH}_2)_n(\text{SO}_2\text{NH}_2)_2$ , wherein  $n =$  integer from 1 to 4.

[0014] The quantity of group a) additives is usually between 0.1 and 2 g/L of solution; the quantity of class b) and c) additives is usually between 1 and 5 g/L. The chrome-plating bath contains 200 to 400 g/L of  $\text{CrO}_3$ , preferably 250 g/L, and 2-4 g/L of  $\text{H}_2\text{SO}_4$ , preferably 3 g/L.

[0015] The electrolytic process can be performed with an average current to the cathode of up to 80 A/dm<sup>2</sup> without any risk of "burning" in the projecting areas with a higher current density.

[0016] The bath temperature is usually between 45 and 60°C.

[0017] In the process in accordance with the invention, a compact layer of chrome with no cracks, with a thickness of approx. 5 microns, is deposited during the first stage, giving the metal beneath it good corrosion resistance. Chrome deposition continues in the same bath with the deposit of a second layer which is substantially microcracked due to the gradual reduction in the inhibitory effect of the additive used, especially the sulphobetaine type, once certain chrome thicknesses are reached. The two-layer chrome-plating thus obtained consequently combines high corrosion resistance with excellent mechanical and lubricant adherence properties.

[0018] At the first stage, which corresponds to the formation of the first layer (or base layer), the method of pulsating-current supply can be used. In this case, a base layer without microcracks can be obtained even with very high thicknesses, thus giving the finished product a very high level of corrosion resistance.

[0019] In known process, after the uncracked base layer of chrome has been applied, additional chrome layers must be applied in a subsequent, different galvanic bath to give the chrome-plated product high corrosion protection (the first layer must obviously be activated to ensure good adherence of the second layer).

[0020] This invention enables the base layer of chrome and one or more successive overlayers to be applied in a single galvanic bath. This enormously simplifies the equipment used and the process compared with the known technique, which requires at least a second chrome-plating bath and a third activating bath.

[0021] Galvanic chrome-plating baths to which alkyl

sulphonic and alkyl polysulphonic acids are added were introduced into industrial practice in the Fifties, and were revived in the Eighties. The aim was to replace the fluorides in the sulphate + fluoride baths used in the known technique, while maintaining the high cathode efficiency of these baths.

[0022] Unfortunately, this proposed alternative to the conventional baths and fluorides was a commercial failure, due to:

- rapid deterioration and consumption of the lead anodes
- degradability of the alkanesulphonic or disulphonic acids into their acid form or their organic salts.

[0023] It has now been found that the use of the additives in accordance with the invention, obtained from nitrogen-containing heterocyclic bases and identified in paragraphs a) and b) above, presents a further advantage, namely that corrosion and encrustation of the lead or lead-alloy anode is much lower than is the case with conventional baths not containing the said compounds.

[0024] Although cathode efficiency is lower than with baths containing known alkanesulphonic acids as additives, the main purpose of this invention is to deposit two layers of chrome in a single operation with a single galvanic bath, strongly reducing lead anode consumption, regardless of cathode efficiency.

#### Example 1

[0025] Chrome is deposited using an electrolyte solution containing:

- $\text{CrO}_3$  250 g/L
- $\text{H}_2\text{SO}_4$  2.5 g/L
- pyridine quaternised with methanedisulphonic acid, 2 g/L
- sulphopropylpyridinium betaine 1 g/L.

[0026] Bath temperature: 58°C, direct current; current density at cathode: 50 A/dm<sup>2</sup>.

[0027] A first, uncracked layer of chrome 5 microns thick is thus formed.

[0028] As chrome electrodeposition continues, a second, microcracked layer (600 microcracks per cm) is formed, making a total thickness of 30 microns.

[0029] The chrome-plating thus obtained has a bright appearance, a hardness of 1000 0.1 HV, and corrosion resistance in saline mist (UNI 5687-73 method) of 125 hours. The corrosion resistance of normal chrome-plating obtained with conventional baths, measured by the same method, is around 40-60 hours, depending on the preparation of the metal base.

#### Example 2

[0030] In a bath with the composition:

- $\text{CrO}_3$  250 g/L
- $\text{H}_2\text{SO}_4$  2.5 g/L
- pyridine quaternised with methanedisulphonic acid, 2 g/L
- sulphopropylpyridinium betaine 1 g/L

bath temperature: 58°C; pulsating current (duration of negative pulse E = approx. 0.3 secs, interval between two negative pulses D = approx. 15 secs); current density at cathode: 50 A/dm<sup>2</sup>.

[0031] A crack-free layer with a thickness of 10 microns is formed.

[0032] Chrome electrodeposition continues with direct current, and a second, microcracked layer (600 microcracks per cm) with a thickness of 20 microns is formed.

[0033] The chrome-plating thus obtained, with a total thickness of 30 microns, has a bright appearance, a hardness of 1000 HV 0.1, and corrosion resistance of 250 hours, measured as stated in Example 1.

#### Example 3

[0034] In a bath with the composition:

- $\text{CrO}_3$  250 g/L
- $\text{H}_2\text{SO}_4$  3 g/L
- methanedisulphonamide 2 g/L
- sulphopropylpyridinium betaine 1 g/L

at the temperature of 58°C, chrome electrodeposition is performed at 20 A/dm<sup>2</sup>.

[0035] A first uncracked chrome deposit with a thickness of 5 microns is thus formed; as chrome electrodeposition continues, and the current density is increased to 45 A/dm<sup>2</sup>, a second deposit of microcracked chrome (600 microcracks per cm) is formed to give a total thickness of 20 microns (5 microns uncracked and 15 microns cracked).

[0036] The chrome-plating thus obtained resembles Example 1 in terms of the characteristics of the chrome deposit.

#### Example 4

[0037] In a bath with the composition:

- $\text{CrO}_3$  280 g/L
- $\text{H}_2\text{SO}_4$  3.5 g/L
- pyridine quaternised with methanedisulphonic acid, 3 g/L
- sulphoethylpyridinium betaine 1 g/L

following the procedure stated in the other examples, the same deposition results are obtained.

#### Example 5

[0038] In a bath with the composition:

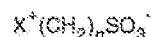
- $\text{CrO}_3$  300 g/L
- $\text{H}_2\text{SO}_4$  3.5 g/L
- methanedisulphonamide 2 g/L
- N-sulphopropylpyridinium betaine 1 g/L

the same mechanical characteristics as described in the preceding examples are obtained.

#### Claims

1. Galvanic chrome-plating process with a multiple layer of chrome, performed in a single electrolytic bath containing 200-400 g/L of  $\text{CrO}_3$  and 2-4 g/L of  $\text{H}_2\text{SO}_4$ , maintained at a temperature of 30-60°C, characterised in that it comprises the following additives able to prevent microcracking of the first layer of chrome, which has a thickness of up to 5 microns:

a) alkanesulphonic acid derivatives of the sulphobetaine type, represented by the general formula:

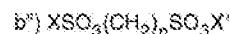


wherein n = 1-8 and X represents a nitrogen-containing heterocyclic base selected from pyridine, pyridazine, pyrimidine, pyrazine, piperazine, methyl pyridine, imidazole, nicotinic acid and quinoline

and at least one of the following compounds:

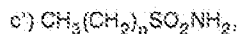


wherein n = 0-2 and X is a protonated nitrogen-containing heterocyclic base of the type indicated in paragraph a) above, and



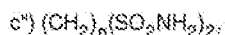
wherein n = 1-3, X and X' are protonated nitrogen-containing heterocyclic bases of the type indicated above, or hydrogen, provided that at least one of X and X' is a nitrogen-containing heterocyclic base

c) sulphonamides of general formula:



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wherein n = integer from 0 to 4



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wherein n = integer from 1 to 4.

2. Process as claimed in claim 1, in which a pulsating-wave current is applied to the electrolytic cell at the first stage, corresponding to the formation of the first, microcrack-free layer. 15
3. Process as claimed in claim 1, in which the sulphobetaine additive is used in amounts of 0.1 to 2 g/L. 20
4. Process as claimed in claim 1, in which the additive comprising a heterocyclic base quaternised with alkane mono- and disulphonic acids is used in amounts of 1 to 5 g/L. 25
5. Process as claimed in claim 1, in which the additive comprising a sulphonamide of alkane mono- and disulphonic acids is used in amounts of 1 to 5 g/L.
6. Process as claimed in claim 1, in which the additives are used simultaneously in the concentrations specified. 30

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Application Number  
EP 01 12 8826

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900 FORM 100-03-02 (9/94/01/1)

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